Pressure safety approach for PIP-II cryogenic distribution system and cryomodules

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The Proton Improvement Plan-II (PIP-II) is a superconducting linear accelerator being built at Fermilab that will provide 800 MeV proton beam for neutrino production. The linac consists of a total of 23 cryomodules of 5 different types. Cooling is required at 2 K, 5 K and 40 K. The cryogenic system must provide protection from over-pressure by sizing pressure relief devices for all volumes and process lines. For the relieving occurring in the linac tunnel, flow must vent to outside to reduce oxygen deficiency hazard.

Cryogenic distribution protection

- Air leaks through open DN80 vacuum evacuation port.
- Account for fraction of LOV heating the metal piping.

<table>
<thead>
<tr>
<th>Circuit</th>
<th>Size</th>
<th>Heat Flux Total Heat load</th>
<th>Heat transfer to metal</th>
<th>TOTAL heat transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA Return</td>
<td>DN250</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HTTS Supply</td>
<td>DN50</td>
<td>0.23</td>
<td>35%</td>
<td>20</td>
</tr>
<tr>
<td>HTTS Shield, simulated</td>
<td>ID 0.15 m dia</td>
<td>2.4</td>
<td>15%</td>
<td>101</td>
</tr>
<tr>
<td>CM</td>
<td>DN250</td>
<td>0.27</td>
<td>15%</td>
<td>0</td>
</tr>
</tbody>
</table>

Cryomodule protection

- No credit taken for metal warming.
- Piping circuits- heat load from peak constant heat flux values.
- Cavities, cold- Air inleaks to beam tube vacuum through 60 mm coupler port. Apply peak heat flux for bare surface area 20 kW/m², which defines requirements.
- Cavities, warm- CDS TL is cold at nominal conditions. 4.5 K He supply valves mistakenly set full open, with return valve closed.

Venting relief devices to atmosphere

- Low Pressure Return- rated at 140 kPa. Collects reclosable SVs exhaust. Ensure backpressure not impacting the 2 K Return reliefs.
- Vent to Atmosphere header- Requirements call for RD flow to vent to outside, not into the tunnel. Utilize dedicated line open to atmosphere at the surface.

Cryogenic distribution vacuum protection

- CDS vacuum jacket DN700, MAWP 150 kPa.
- Vacuum segmentation: 71 m for surface, 104 m and 106 m tunnel.
- Fluid expands from external and shield warming.
- Results: Total relief area per segment defined. Propose two 70 mm reliefs on each Tunnel Transfer Line Bayonet Can.

Acknowledgment This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.